COLLEGIATE INSTRUCTION IN METEOROLOGY.

By CHARLES F. BROOKS, Meteorologist, Weather Bureau.

[Dated: Washington, D. C., Jan. 22, 1919.]

The war-time demand for 600 meteorologists well trained in physics and mathematics showed that there were but a handful of such men available in the United States. Obviously, something had been lacking in our scientific education. The Signal Corps met the immediate situation, first, by having the Weather Bureau give about 200 young engineers and other scientists a preliminary training, which was finished in France; and, second, by establishing in this country a Signal Corps School of Meteorology to train the remaining number needed.[1] The recognition of the importance of meteorology in warfare led to the inclusion of a course of meteorology in the work of the Students' Army Training Corps. Now that colleges are revising their curricula in the light of lessons taught by the war, meteorology is beginning to receive consideration not accorded it before.

In most colleges where the subject is touched upon meteorology is taught in conjunction with physical geography. Therefore the teacher is a geographer or geologist, with, perhaps, but little knowledge of the physics of the air. In his hands, the course is, necessarily, mostly descriptive. The textbook describes and illustrates, the lecturer may add some personal notes and interpretations; and the laboratory assistant presides over simple exercises, such as observing and reducing the readings of instruments, and constructing and describing isothermal or isobaric maps. The course usually ends with a trip to the local office of the Weather Bureau. "Interesting and easy" is the students' universal verdict. Some take the elementary course; few or none push themselves into advanced work, in which no instruction is offered.

In some of the larger universities, meteorology and climatology are taught together in the department of geography. Here the instructor knows and teaches his subject well, although he may not be enough of a physicist to make his meteorology a course as rigorous as physics. Much of the emphasis is climatological rather than physical, for meteorology is taught as the forerunner of climatology, or as a background to geology and geography. The enthusiastic student is drawn more easily into the regular advanced courses in regional climatology than into the research course or courses which offer the only advanced work in meteorology.

In a few colleges, meteorology is taught in the department of physics. The association is all that could be desired;[2] but, unfortunately, there are few physicists who know meteorology well enough to teach it satisfactorily. In most branches of physics, the laboratory work is work of precision carried on indoors under carefully controlled conditions. Some experiments in meteorological physics can be conducted in the laboratory; but the vast majority of the experiments are conducted by Nature in such a way that man can only observe processes and results without being able to control the conditions of the experiments.[3] As the geologist and geographer work largely in the open, they generally know more about the weather than does the physicist, and so are better prepared to teach meteorology than is the physicist.

The content of meteorology is easily described as *the weather and its elements*. A college course in meteorology may well include the following lines of work: (1) Daily instrumental and non-instrumental observations to be recorded in a graphical, consecutive picture of the weather, and to be discussed briefly; (2) a systematic study of meteorology as a branch of physics, presented mostly by lectures; (3) laboratory study of instruments; various exercises; and practice in the construction of weather maps and in forecasting; and, possibly, (4) one or more special papers on meteorological topics.

The work should extend over as long a period as practicable. If it is confined to less than two months, neither the students nor the teacher can be satisfied with the abbreviated presentation of the subject. Even if the students devote all their time to meteorology, two months is too short to get an intimate knowledge of the weather; for to understand the weather it is necessary to observe its various phases, not once, but many times. The obvious general arrangement for a study of meteorology would be to observe the weather carefully day after day while investigating, first, each element separately, and, second, the weather as the combination of these elements.

(1) *Daily observations.*—Beginning with the first meeting of the course, the instructor should establish the regular practice of spending five minutes with his class in the open for observing the weather every time he has any of his students assembled. At the first session of the course each student may be started making and recording simple weather observations. Observe the amount of cloudiness, the wind, the occurrence of rainfall, and the visibility. At first, it will be sufficient detail to record the cloudiness as "cloudy," "partly cloudy," or "clear," the wind direction to the nearest of eight points, the velocity in such terms as "calm," "light," "moderate," "strong," and "gale." In recording rainfall, the times of beginning and ending, with, perhaps, some note as to the intensity of the rain, may be sufficient. Visibility is usually expressed in terms of the distance at which well-defined objects are visible.[4]

It will hardly be found practicable to have the students take observations at times other than those when assembled for classroom or laboratory work, although they may be encouraged to make optional observations three times daily, morning, afternoon, and evening. At each meeting with the instructor the students should be asked to make their individual observations and hand them to the instructor. Then the instructor will read his observations aloud and give a brief explanatory talk on the weather since the last observation and on what the local signs indicate for the next few hours. The observations may be marked and returned to the students at the next meeting, and then they can enter them in a notebook. The tabulation of these observations may be made graphical by the use of the international symbols, repeating what is indicated in words or abbreviations. Arrows flying with the wind and having one to four double barbs, according to the velocity, may be used for the wind symbols.

Observations of temperature and pressure may soon be added. These observations can not very well be taken by each student more than once daily, if as often as that, but the observations made by any one can be posted and used by all to make graphs similar to the records of the thermograph and barograph.

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[1] See M. W. R., Dec., 1918, 46: pp. 560–562.

[2] See the introductory part of Prof. W. J. Humphrey's paper, "Some recent contributions to the physics of the air," Science. 1919 (M. W. R., Dec. 1918. 46: 563–564).

[3] Prof. W. S. Franklin has discussed this in detail in "A much needed change of emphasis in meteorological research," M. W. R., Oct., 1918, 46: 449–453.

[4] The best publication on visibility is that by Sir Napier Shaw: "Memorandum on Atmospheric Visibility." Published for the Naval Meteorological Service Hydrographic Dept., [British] Admiralty, Feb., 1918, 8°, 18 pp. (Abstract is to be published in a later issue of the M. W. R.)

By the time the subject matter of the course reaches "clouds" the daily meetings with the instructor in the open will have acquainted the students with the different cloud forms sufficiently to enable them to make these observations individually. The clouds occurring at different elevations should be recorded separately, the highest clouds at the top. Where two or more cloud forms occur at the same level, as is frequently the case when there is a sheet of alto-stratus fringing off into strato-cumulus and alto-cumulus, it is well to use only the abbreviation of the dominant type. For each cloud type the number of tenths of the sky covered should be

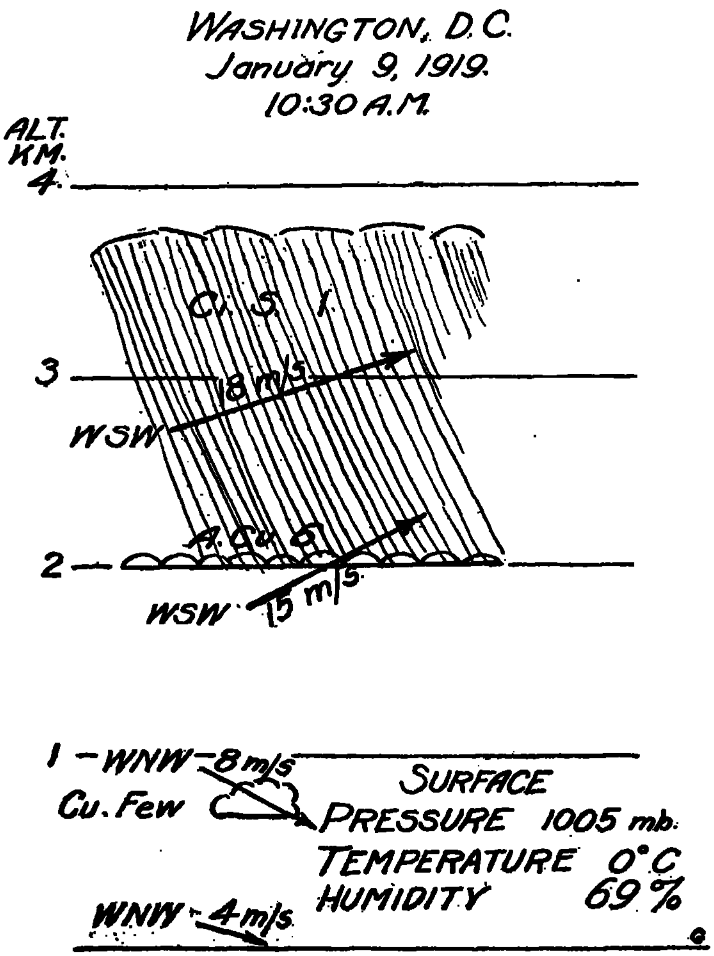

FIG. 1.—Graphic cross-section of the lower air. The diagonal streaks marked "Ci. S." represent that the snow crystals of which the cirro-stratus cloud was composed fell to a considerable distance below the top of the cloud, and in many places even fell through, and partially obscured the layer of alto-cumulus below. The directions of the arrows are entered as if on a map, and their lengths are roughly proportional to the wind velocity. The indicated altitudes of the Ci. S. and A. Cu. are hypothetical.

recorded, and a little later the direction of movement from the nearest of 16 points should be observed and entered.

With the consideration of winds in the systematic work of the course, the students' observations may be refined still further. Once a week or oftener, when clouds at several levels are visible, each student should make for himself a detailed meteorological observation, including pressure, temperature, humidity, wind direction and velocity, cloud direction and relative (angular) velocity, and from this he should construct a diagrammatic cross-section of the conditions at different elevations in the lower atmosphere. Except for the observations of pressure, temperature, and humidity, no instruments are required. The direction of the wind and of the clouds at the different levels should be observed to the nearest of 16 points. The velocity of the wind may be estimated according to the Beaufort scale and then converted into meters per second. If the altitude of a cloud is estimated, using the average or most frequent altitude of the cloud form as a guide, and if the angular rate of movement, say, in fractions of a radian per minute is observed, even without instruments, cloud velocities may be obtained with fair accuracy by simple trigonometry. The altitude of bases of cumulus clouds may be computed by the "dew-point formula," and the heights of the tops or other features may be obtained by proportional measurements.[5] The results of this observation may be shown graphically on a diagram as in figure 1.

The students' observations of clouds, winds, and miscellaneous phenomena may be recorded in some such form as the following:[6]

NON-INSTRUMENTAL WEATHER RECORD.[7]

C. F. BROOKS, COLLEGE STATION, TEXAS. — JULY, 1918. 90th Mer., "SUMMER TIME."

Date.	8 A. M.			2 P. M.			8 P. M.			Remarks.
	Clouds and Wind.†			Clouds and Wind.			Clouds and Wind.			Rain, Haze, Miscellaneous Phenomena.
	Amt. 0–10	Kind.	Dir.	Amt. 0–10	Kind.	Dir.	Amt. 0–10	Kind.	Dir.	
8	0	0	0	2	Cu.	ENE	2	Ci. S.	NE	Vis. 5 km. at 2 P.
							2	S.Cu.	ENE	
	○	Lt.	W	○	Mod.	ESE	◑	Mod.	SE	
9	4	Ci.S.	NE	1	Cu.	NE	2	Ci.S.	S	Vis. 6 km. at 2 P.
							2	A.Cu.	NW	Vis. 10 km. at 8 P.
							4	Cu.N.	SSE	◍° 6:00–6:15 P.
	◑	Lt.	NW	○	Lt.	N	●	Mod.	SE	
10	4+1*	Ci.S.	NNW	3	Ci.S.	NNW S	1	Ci.	NNW	Vis. 9 km. at 2 P.
							3	Ci.S.	S	
	Few.	Ci.Cu.	NNE							
	5	S.Cu.	SSW	5	Cu.	N (top) S (base)	2	S.Cu.	NE	⊕ 4-5 P.
	●	Lt.	SE	◑	Lt.	N	◑	Mod.	SE	

† Under each date the wind is indicated on the last line: "Lt. W" is light west wind.
* When an upper cloud layer is surely more extensive than those parts of it visible at one time, the additional amount of such a sheet of clouds may be indicated after a plus sign following the number of tenths actually visible.

With the beginning of the consideration of cyclones and anticyclones the individual weather records may be discontinued in favor of a single one for the class as a whole. On a long roll of wrapping paper 3 feet or more wide the instructor, with the help of his students, should keep a detailed graph of the weather, continuing day after day. The form shown in figure 2 is offered as a suggestion. Such a graph made on a large scale and discussed each day will go far toward unifying the students' conception of the weather as made up of a great many elements which are closely interdependent.

As the last advance in the open-air observations by the individuals of the assembled class, individual forecasts from local signs may be handed to the instructor instead of the usual weather observations.

This program of open-air observations is essentially that evolved at the Signal Corps School of Meteorology.

(2) *Lectures.*—Three general outlines of courses in meteorology may be of interest. One is an elementary

[5] Detailed discussion of cloud forms, and methods of observing cloud velocities are contemplated for a "Cloud number" of the MONTHLY WEATHER REVIEW, to appear in three or four months.
[6] This form is, of course, recommended only for purposes of instruction and not for keeping the records of an observatory.
[7] This is a true cloud record, but only approximate for surface winds and miscellaneous phenomena.

course of general meteorology, in which physics is emphasized and climatological aspects are given some attention; a second is a course solely on the physics of the air; and a third is a course of general meteorology which university, and so must be presented without a presumption of knowledge of much physics or mathematics on the part of all members of the class. Nevertheless, the physics of the atmosphere is given all possible atten-

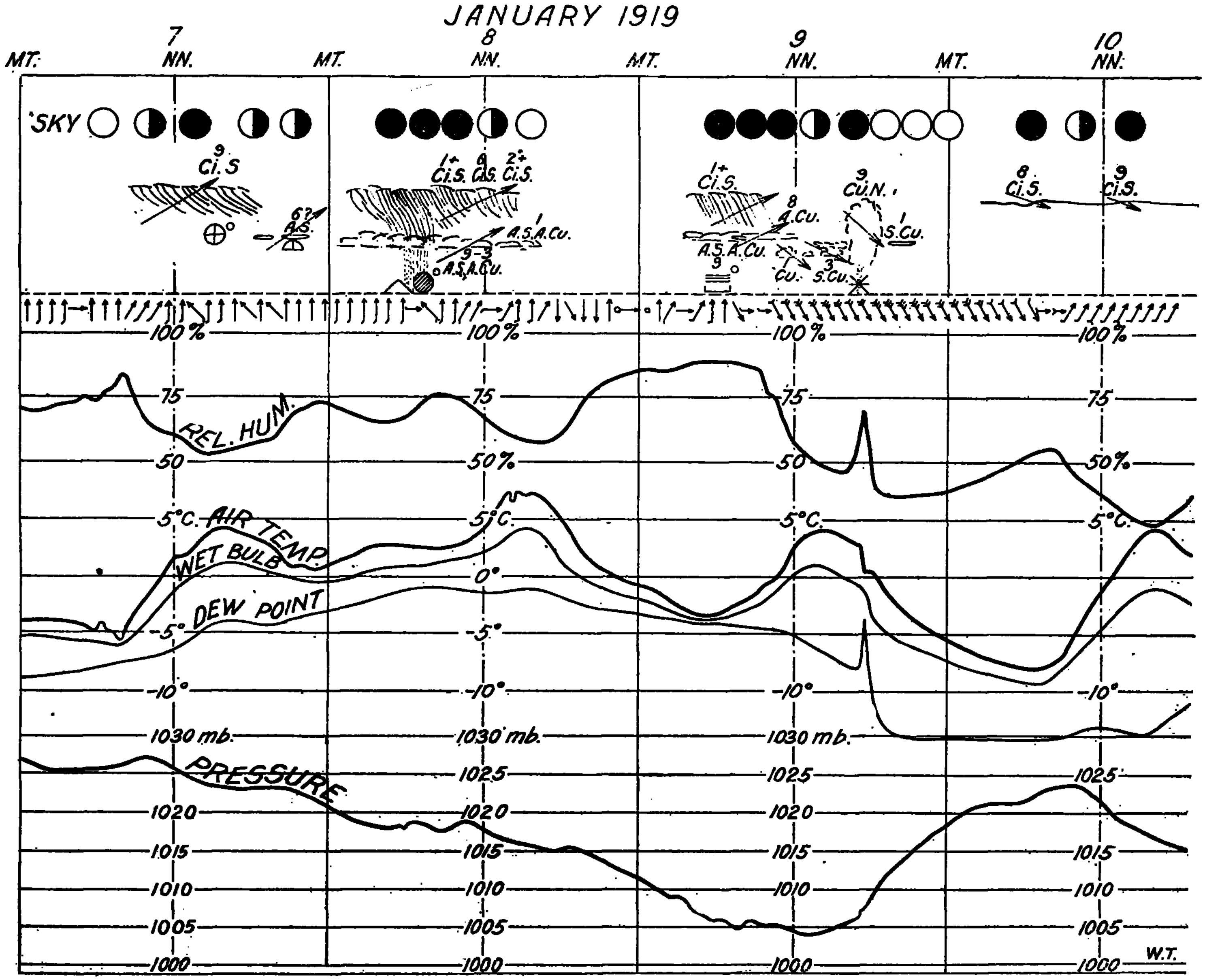

FIG. 2.—Wall chart of the daily weather. Cloud observations made at Washington, D. C., by C. F. Brooks, supplemented by transcripts and computations from instrumental records at the Central Office of the Weather Bureau.

Clouds and miscellaneous phenomena.—International symbols and abbreviations have been used. Actual measurements of the clouds not having been made, their apparent relative heights are indicated, and some attempt has been made to portray their appearance. Since the clouds move generally from the west, and since in most weather or other continuous time diagrams, the later dates are to the right, it is best to represent the clouds as if projected on a vertical plane south of the observer. The directional arrows are drawn as if on a map (as in Fig. 1).

Winds.—Hourly directions and velocities (one barb for each Beaufort number) are shown as if on a map, the arrows flying with the wind.

Relative humidity was taken from the hygrogram corrected by psychrometer observations thrice daily.

Temperatures.—*Air*, from corrected thermogram; *Wet bulb* and *Dew point*, from the thrice daily psychrometer observations, with intermediate values obtained by humidity tables from the hygrogram and thermogram.

Atmospheric pressure was plotted from the trace of a mercurial barograph. After the temperature and pressure curves were drawn, the scales were converted to read in degrees centigrade and in millibars, respectively.

is largely physics of the air, and which has more emphasis on immediate applications, such as forecasting, than on climatology.

The first outline is that of Prof. R. De C. Ward's lectures at Harvard. His course is open to anyone in the tion considering (1) that this course is taken by students specializing in geography and geology rather than in physics, and (2) that this course is a prerequisite for the courses in general climatology, regional climatology, instruments, and research in meteorology and climatology.

GENERAL METEOROLOGY.

OUTLINE OF THE ELEMENTARY COURSE AT HARVARD UNIVERSITY.

By Prof. R. DE C. WARD.

Lectures.	Outline.
	Introduction.
2....	I. The atmosphere: Extent and arrangement about the earth.
	II. The control of atmospheric temperatures by the sun:
1....	A. Heating and cooling of the atmosphere.
	B. Radiation, conduction, convection, mixture by winds.
1....	Colors of the sky.
	C. The measurement and distribution of temperature.
3....	1. Thermometry.
2....	2. Charts of temperature distribution.
2....	III. Pressure. Barometers. Pressure changes. General relations of pressure and winds.
	IV. Winds:
1....	A. Instruments.
2....	B. Convectional circulation and its applications.
1....	Deflective effect of the earth's rotation.
4....	C. Classification of the winds, and discussion of general and local winds.
	V. Moisture:
1....	A. Sources, evaporation, measurement, distribution.
	B. Condensation.
4....	1. By radiation and conduction, by mixture, by expansion.
2....	2. Dew, frost and clouds.
1....	VI. Vertical temperature gradients: Distribution of temperature in the free air: Adiabatics and retarded adiabatics.
	VII. Winds and weather of our weather maps:
	A. Extra-tropical cyclones and anticyclones.
1....	1. Characteristics of cyclones and anticyclones: At the surface and aloft "gradient wind;" actual paths of cyclonic winds.
2....	2. Forecasting.
1....	3. Theories of origin of cyclones and anticyclones.
1....	4. Special types of winds associated with cyclones and anticyclones.
2....	B. Tropical cyclones.
2....	C. Thunderstorms.
1....	VIII. Atmospheric electricity.
2....	IX. Tornadoes and waterspouts.
2....	X. Rainfall.
1....	XI. Weather and climate.

A few points which may seem arbitrary in the arrangement of the subject matter deserve mention. A consideration of vertical temperature gradients is left until after winds and moisture have been taken up, for the distribution of temperature in the free air depends not only on the effects of sunlight, radiation, and conduction, but also on convection and the latent heat from water vapor condensing in the atmosphere. Tornadoes and waterspouts seem unnecessarily separated from thunderstorms, with which they are almost, if not quite, invariably associated; atmospheric electricity, however, surely requires treatment just after thunderstorms. Rainfall is not discussed immediately following evaporation and condensation, for the distribution of rainfall depends largely on cyclonic and thunderstorm action, which precipitate the moisture from the atmosphere. Prof. Ward's very logical arrangement of his lecture material is the outcome (by no means final) of his extensive experience in teaching general meteorology.

The second outline is that of Prof. W. J. Humphreys's partially published work, the Physics of the Air,[8] which has been followed essentially by the author in two presentations of a course on this subject to Weather Bureau men.

[8] Journ. of the Franklin Inst., 1917 and 1918. See notice in this issue of the MONTHLY WEATHER REVIEW, 1918, 46: 562.

THE PHYSICS OF THE AIR.

GENERAL OUTLINE OF A WORK COMPILED FOR THE WEATHER BUREAU AND PUBLISHED* BY COOPERATION WITH THE FRANKLIN INSTITUTE—USED IN AN ADVANCED COURSE OF INSTRUCTION AT WASHINGTON.

By Prof. W. J. HUMPHREYS.

Divisions on basis of 40 units.	Outline.
2........	I. Observations. Sources of meteorological information.
	II. Temperature:
1........	A. Some theoretical temperature relations of the atmosphere.
1........	B. Observed vertical temperature gradients.
2........	C. Isothermal region, or stratosphere.
2........	III. Composition of the atmosphere. Barometric hypsometry.
2........	IV. Insolation.
	V. Atmospheric circulation:
1........	A. Introductory: Vertical convection; classification of winds.
1........	B. Winds due to local heating, local cooling, or both.
	C. Winds due to widespread heating and cooling.
4........	1. Wind in general. Gradient wind.
1........	2. Monsoons. Trade winds.
3........	3. Cyclones and anticyclones.
1........	4. Forced winds. Tornado.
1........	VI. Barometric fluctuations.
	VII. Moisture:
2........	A. Evaporation and condensation.
2........	B. Fogs and clouds.
3........	VIII. The thunderstorm and its phenomena.
1........	Lightning.
1........	IX. Atmospheric electricity.
6........	X. Optics.
3........	XI. Factors of climatic control.

It will be noted that this outline contains no reference to anything but the processes of the atmosphere: the geographical distribution of temperature, humidity, cloudiness, and rainfall are not discussed; and neither are applications of meteorology dwelt upon. The order, which at first sight looks irrational, is adjusted to the observer's point of view. First, how do we observe the phenomena of the atmosphere? Second, what are the features of that most obvious element, the temperature of the air? Third, why do we have such temperatures? The answer to this third question involves the composition of the atmosphere, and insolation. The composition of the upper air can not be discussed without a consideration of barometric hypsometry, so this is introduced here. After temperature, the circulation of the atmosphere, which depends on pressure differences induced by the uneven distribution of temperature, demands attention. Then barometric fluctuations, which are caused by winds, may be introduced. Moisture comes next. Finally, each of the elements having been considered, that highly complex phenomenon, the thunderstorm, is treated in detail. Lightning leads to atmospheric electricity; then follows optics; and a consideration of the factors of climatic control closes the work.

The third outline is essentially that employed at the Signal Corps School of Meteorology, at College Station, Tex., in 1918. Of Division VIII, only the section on aeronautical meteorology was touched on in these Signal Corps courses. The outline was arranged originally for college upper classmen; then modified for sophomores at Yale; and, finally, in the form here presented, used with classes of mature men, most of whom were graduate engineers, the rest being largely physicists, mathematicians, chemists, science teachers, and Weather Bureau observers.[9]

* Except divisions X and XI.

[9] See the article on the Signal Corps School of Meteorology, on pp. 560-562 of this issue of the REVIEW.

GENERAL METEOROLOGY.

OUTLINE OF COURSE AT THE SIGNAL CORPS SCHOOL OF METEOROLOGY, COLLEGE STATION, TEX., 1918.

By CHARLES F. BROOKS.

Lectures.	Outline.
1.....	Introduction: Meteorology.
2.....	I. Physical properties of the atmosphere.
	II. Temperature:
2.....	A. Sunlight and radiation.
4.....	B. Course of temperature on land and water surfaces and in the overlying air.
3.....	C. Vertical and geographical distribution of temperature.
1.....	III. Atmospheric pressure:
1.....	A. Vertical decrease of pressure. Hypsometry.
1.....	B. Pressure changes.
	IV. Winds:
1.....	A. Convectional circulation.
2.....	B. Gradient wind.
1.....	C. Wind friction and its results.
	1. Vertical increase of velocity in the lower air.
	2. Gustiness.
	3. Diurnal period of velocity and direction.
1.....	D. Pressure distribution and winds of the world.
	V. Moisture:
2.....	A. Water vapor; evaporation, humidity, and condensation.
3.....	B. Clouds: Forms and their genesis, heights, velocities; prognostics.
2.....	C. Precipitation: Causes, forms, distribution.
	VI. Weather:
3.....	A. Cyclones and anticyclones, considered as units.
2.....	B. The weather around and in cyclones and anticyclones.
3.....	C. Local storms; thunderstorms, squalls, tornadoes, and waterspouts.
3.....	VII. Weather forecasting.
1.....	VIII. A. Aeronautical applications of meteorology.
1.....	B. Agricultural, engineering, business, and commercial aspects of the weather.
1.....	C. Physiological effects of weather and weather changes.

In content, this course is between Prof. Humphreys's and Prof. Ward's; there is less physics than in the former and less climatology than in the latter. The arrangement is simpler than either of the other two, although this simplicity may be at the expense of the best presentation of the elements in their logical interrelations.

These three outlines are not recommended for adoption, but are presented as examples, in the hope that they may prove helpful to those who teach, or are about to reach, meteorology.

In preparing the lectures, the instructor will find Prof. Humphreys's "Physics of the Air" invaluable; and he will do well to have at hand the text and reference books mentioned below. Such magazines as the MONTHLY WEATHER REVIEW, Geographical Review, Science, Nature (London), Scientific American and Supplement, should be watched so that the most recent advances in meteorology may be summarized and incorporated in the lectures, thereby keeping them full of immediate interest. Similarly, the students should be encouraged to bring in meteorological clippings from magazines and newspapers. Lecture note-taking may well be encouraged, or better still, required. If diagrams are to be incorporated in the notebooks, it is almost essential that the instructor draw them on the blackboard during his lecture. Carefully prepared diagrams, prints, or photographs are excellent illustrative material, but the student will be discouraged by their finished character from attempting a sketch which he may not be able to complete without losing some of the lecture. Lantern slides are more convenient than wall charts and enlarged photographs, but a class will not take notes in a darkened room. Slides may be used, nevertheless, to good advantage in review lectures.

There is as yet no suitable textbook for the general course in meteorology. Prof. W. M. Davis's, Elementary Meteorology,[10] though published 25 years ago is today the clearest and most logical book for teaching use in any language. For those parts which are now out of date, paragraphs from Prof. W. I. Milham's Meteorology [11] may be substituted. Other works which contain valuable information, but which are not so suitable as textbooks are: W. L. Moore's, Descriptive Meteorology,[12] good for reference; Alexander McAdie's, Principles of Aerography,[13] useful for its discussion of the various lines of advance of meteorology during the last few years; F. H. Bigelow's, Atmospheric Circulation and Radiation, a difficult mathematical treatise[14]; the Weather Bureau's, Introductory Meteorology [15] issued for the Students' Army Training Corps last fall; the British Meteorological Office's, Meteorological Glossary [16]; Sir Napier Shaw's, Forecasting Weather,[17] and his more extended, voluminous, Manual of Meterology [18]; Julius von Hann's, Lehrbuch der Meteorologie,[19] the most comprehensive bibliographic work on meteorology; and W. J. Humphreys's, Physics of the Air,[20] the most thorough discussion of the physics of the air—of interest to the student who is willing by close application to study the fundamentals of meteorological physics.

(3) *Laboratory work.*—By far the most extensive and systematic set of laboratory exercises in meteorology, is that developed by Prof. Ward at Harvard. Some idea of the scope of these exercises may be had by referring to his book, "Practical Exercises in Elementary Meteorology"[21]; but since this book was published, so much improvement has been made that it is to be hoped that Prof. Ward will publish his exercises as they are today.

Every course in general meteorology should have detailed laboratory work (1) in meteorological instruments, observations, and forms; (2) in interconversions of temperature and pressure and linear units in conjunction with mapping and graphing the horizontal and vertical distribution of temperature, pressure, and moisture; (3) in the interrelations of the weather elements leading to making and verifying weather forecasts from local observations and weather maps.

(4) *Special reports* on topics chosen by each student for himself and presented orally to the class will serve the double purpose of making the individual a specialist in at least one phase of the subject, and of showing the class that meteorology is a growing science.

The student who does creditable work in a good college course in meteorology, even if this course extends over only one term, will have the basis from which he can make himself a meteorologist. He will know something of how to observe and record the weather; he will be able to interpret to some extent the phenomena of the atmosphere; and, if need be, he can forecast the weather with moderate success. He will not be an expert meteorologist, but he will know how to become one.

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[10] Boston, 1894, 4°, 355 pp.
[11] New York, 1912-1917, 4°, 450 pp., 50 charts.
[12] New York, 1910, 4°, 344 pp., 45 charts.
[13] Chicago, 1917, 8°, 318 pp. For discussions, see Science, 1917, N. S., vol. 46, pp. 264-266, and 360; Geog. Rev., 1918, V, pp. 167 and 256.
[14] See mention on p. 563 of this issue of the REVIEW.
[15] New Haven, 1918, 8°, 149 pp. See review on pp. 562-563 of this issue of the REVIEW.
[16] See mention on p. 563 of this issue of the REVIEW.
[17] London, 1913, 8°, 380 pp., 159 figs.
[18] Cambridge, 1919, pts. 1-3 not yet issued: pt. 4, 4°, 160 pp.
[19] Leipzig, 1915, 3d ed., 4°, 847 pp., diagrams, tables, plates.
[20] Loc. cit.
[21] Boston, 1899, 8°, 199 pp.

The demand on the part of artillerists, aviators, and many other military units for weather information and forecasts has demonstrated that meteorology is a subject worthy of the time of more than a mere handful of investigators. The growth of aviation alone and the promise it holds points to a quick rise of interest in the study of the physics of the air. Students who desire to specialize in meteorology need no longer be told that the master or doctor of meteorology must look forward to probable unemployment in his chosen field of work.

Specifically, what are some of the lines of work demanding services of meteorologists? Business, farming, transportation, aviation, research and teaching all need men who know meteorology. Large business concerns have men who constantly watch the weather from the point of view of its effects on their work. For example, general merchandise and hardware concerns buy stock with a view to the probable demand for the different lines several months later; a demand which for many lines of goods is closely dependent on the weather. Without making a study of present and probable weather,[23] these concerns would lose much by having an excess of one kind of stock and not enough of another.

Every farmer is his own local forecaster, and usually he is a good one, for his outdoor life and his direct interest make him familiar with the weather. A large farming corporation, however, needs more than the indications from local signs. A meteorologist to direct the farming, storing and shipping operations would save much produce in the course of the year, and would be able to have the goods reach the markets at the times when prices are best. At Medford, Oreg., in 1912, the fruit growers employed their own frost expert.

Railroads, particularly street-railway companies, have every reason to want in the traffic department a man who knows some meteorology.[23] The question frequently arises, "Snow is forecast for to-night—shall I hold 1,000 men ready to clear the tracks? They would be needed only if the fall exceeds 2 or 3 inches." Motor-truck freight companies in their operations depend considerably on the weather.

In aviation, the wind directions and velocities at different elevations are of great concern. For instance, a wind of 60 miles an hour is to be sought if it blows toward the aviator's goal; but avoided otherwise. To keep informed of the winds of the free air all over the United States will require observations of pilot balloons a few times daily at perhaps 100 places.[24] To chart, and to study these observations will require the work of a large number of men. The openings for aerologists are limited only by the expansion of flying.

The highest specialists in meteorology are needed for research work and teaching. Some subjects worthy of research are indicated in the list on pages 566–567 of this issue of the REVIEW. Research workers would be supported mostly by the universities,[25] by business men, or by the Weather Bureau. To meet the growing demand for meteorologists, there is imperative need of an increasing number of teachers of meteorology.

[22] See "Relation of weather and business in regard to rainfall," Special bulletin, Chamb. of Comm. of the U. S. A., Washington, D. C., Feb. 14, 1919, 4°, 12 pp.

[23] Every November the New York Central Railroad issues a "Chart of mild and cold winters," for the winter guidance of maintenance of way engineers and rolling stock superintendents. The Sixth Annual Weather Issue (by P. H. Dudley, consulting engineer, rail, tires, and structural steel, New York, Nov. 14, 1918), contains a letter; a table of monthly mean temperatures at 16 stations; a chart of departures of monthly temperatures from these means, 1911–1918; and a mention of the operating character of each winter.

[24] There are now only about 30.

[25] In the American Meteorological Journal are articles by Cleveland Abbe on "The needs of meteorology" (1893, XI; 560–562), and "Meteorology in the university" (1896, XII; 312–317), which call for the endowment of universities for meteorological work on a scale commensurate with astronomy; and which outlines a thorough course in such an establishment.

A SIGNAL CORPS SCHOOL OF METEOROLOGY.[1]

By OLIVER L. FASSIG, Chief Instructor, Signal Corps, U. S. Army.

[Dated Washington, Dec. 25, 1918.]

The value of an intimate knowledge of weather conditions—actual and prospective—in war operations is obvious. The many practical applications of this knowledge in artillery fire, in aviation, in gas and flame attacks, in bombing expeditions, and in many other military and naval operations, have received special attention during the past year in the Signal Corps of the Army. One of the duties of the Science and Research Department of the Army is the supervision of all research and development work in meteorology, under the direction of Lieut. Col. R. A. Millikan. By special mention this includes the furnishing of information of surface and upper air conditions to all branches of the Army, and the training of all meteorological personnel.

Early in the fall of 1917, a meteorological section of the Science and Research Department was planned and steps were immediately taken by Col. Millikan, in cooperation with Prof. C. F. Marvin, Chief of the Weather Bureau, to form an organization to provide for the necessary special training of approximately 1,000 men, and for procuring the essential instrumental equipment for stations. The only existing source from which trained weather observers could be drawn was the United States Weather Bureau. As the bureau had already contributed a considerable number of its observers to various branches of the military and naval service, any additional withdrawals would seriously cripple the essential work of the Bureau. Hence plans were made for the special induction of the needed men into the Signal Corps for training and service as weather observers.

As time was a matter of prime importance, the first contingencies of inducted men were sent to a score or more of Weather Bureau stations, located in all sections of the country, in groups of two or three, to eight or ten. Here they were given practical instruction for a period of eight to ten weeks in the duties of observing and recording weather conditions, in the preparation of forms, in the use and theory of instruments, and in the preparation and interpretation of weather maps, under the supervision of the official in charge of the station. In this manner about 200 men were prepared for duty overseas and in this country between September, 1917, and April, 1918. Upon arrival in France the men were given an additional short course in review and in such new applications of their knowledge as were developed at the front.

The instruction at the stations of the Weather Bureau was intended only as a provisional plan to obtain quick results. Early in the spring of 1918 a special school for the training of the men was organized, as it was evident that better results would doubtless be obtained, and with less inconvenience to the Weather Bureau, by standardizing the course of instruction and collecting into one school and under one instruction staff as many men as could be satisfactorily provided for under existing conditions. The first class was organized at Camp McArthur, Waco, Tex., in April, 1918. Before completion of the organization the school was transferred to the Agricultural and Mechanical College of Texas, at College Station, in the latter part of May, 1918. The instruction staff consisted of:

Dr. Oliver L. Fassig, Chief Instructor and Director.

Dr. Charles F. Brooks, Instructor in general meteorology and cloud observation.

[1] Read at the Baltimore meeting of the Association of American Geographers, Dec. 28, 1918.